Effect of PNF stretch techniques on knee flexor muscle EMG activity in older adults

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Received 17 December 2001; received in revised form 17 May 2002; accepted 5 June 2002

Abstract

The effects of proprioceptive neuromuscular facilitation (PNF) stretch techniques on older adults are unknown and the physiological changes associated with aging may lead to differential responses to PNF stretching. Therefore, the purpose of this experiment was to examine the effects of PNF stretch techniques and EMG activity in older adults. Three PNF stretch techniques: static stretch (SS), contract–relax (CR), and agonist contract–relax (ACR) were applied to 24 older adults aged 50–75 years. The subjects were tested for knee extension range of motion (ROM) and knee flexor muscle EMG activity. The results indicated that ACR produced 29–34% more ROM and 65–119% more EMG activity than CR and SS, respectively. It was concluded that PNF stretch techniques can increase ROM in older adults. However, a paradoxical effect was observed in that PNF stretching may not induce muscular relaxation even though ROM about a joint increases. Care should be taken when applying PNF stretch techniques to older adults due to age-related alterations in muscle elasticity. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Older adults; PNF; EMG; Range of motion

1. Introduction

Proprioceptive neuromuscular facilitation (PNF) techniques make use of proprioceptive stimulation for the strengthening (facilitation) or relaxation (inhibition) of particular muscle groups [1,2]. One principle of PNF maintains that voluntary muscular contractions are performed in combination with muscle stretching to reduce the reflexive components of muscular contraction, promote muscular relaxation, and subsequently increase joint range of motion (ROM) [1,3]. PNF stretch techniques have been demonstrated to increase joint range of motion as compared to non-PNF stretch techniques [4,5]. Tanigawa [4] compared PNF stretch techniques to passive mobilization and reported that the PNF procedure resulted in greater gains in ROM. Sady et al. [5] compared PNF, static, and ballistic stretch techniques on shoulder, trunk, and hamstring muscles and reported that the PNF stretch procedures achieved significantly greater gains in ROM at all three joints compared to the other stretch techniques.

Resistance to musculotendinous stretching involves both the mechanical viscoelastic properties of muscle and connective tissue, as well as the neurological reflexive and voluntary components of muscular contractions [6–9]. PNF stretch techniques are believed to reduce reflexive components that stimulate muscular contraction and thereby enable joint range of motion to increase [3]. However, few studies have provided neurophysiological evidence as to the effectiveness of PNF stretch techniques [6–9]. In contrast to the theoretical basis, previous investigations have also shown that while PNF techniques achieve a gain in ROM, electromyographic (EMG) activity in the muscle being stretched is not necessarily reduced and in some cases is actually increased [6–9]. These studies suggest a paradoxical ROM/muscle tension relationship in that PNF stretching may not induce muscular relaxation even though ROM about a joint increases.

Little is known about the effects of PNF as a method...
to increase joint ROM on older adults. Ferber et al. [10] examined the effects of PNF stretch techniques in trained and untrained older adults and reported that PNF stretch techniques can be used to increase knee joint extension ROM in older adult populations depending on activity level and age. However, these authors did not measure knee flexor EMG activity and the effects of PNF stretch techniques on muscle EMG activity in older adults remains unclear.

It has been reported that biological changes associated with aging are related to a loss of joint range of motion in individuals past the fourth decade of life [11–15]. These individuals have also been demonstrated to exhibit increased muscle stiffness [16,17], muscle atrophy [18], increases in type I collagen [19] as well as a reorganization of the motor unit [20]. In light of these changes, older adults may demonstrate a differential response to increases in joint ROM and muscle EMG activity during the application of PNF stretch techniques compared to young adults. Therefore, the purpose of this experiment was to examine the effects of PNF stretch techniques on knee joint ROM and EMG activity in older adults. Based on the physiological changes that occur in individuals past the fourth decade of life, it was hypothesized that older adults would exhibit no differences in joint ROM or muscle EMG between the three PNF stretch techniques.

2. Methodology

2.1. Subjects

Twenty-six male subjects (55–75 yr) volunteered to participate in the study. All subjects were healthy, active older adults partaking in low-intensity health-maintenance activities such as golf, walking, and gardening. No subject had a prior history of lower extremity infirmity or pathology within the year prior to testing or at the time of testing and none was suffering from osteoarthritic or musculoskeletal disease that may have affected the ability to perform the tests. No subject was currently taking any medication specifically designed to effect musculoskeletal tissue such as anti-inflammatory, pain relief, or arthritic medication. All subjects gave their consent in accordance with the university’s policy on research using human subjects.

2.2. Procedures

The study was designed to assess knee extension ROM and knee flexor activation following three PNF stretch techniques. The method of stretch application was similar to methodology reported in other investigations [8–10]. Subjects were positioned supine on a padded table with the non-dominant thigh fixed by straps at zero degrees of hip flexion (Fig. 1A). The dominant thigh was fixed by straps at maximal hip flexion according to the procedure of Evjenth and Hamberg [21].

Three types of PNF stretches were applied to each subject with order of stretch type counter-balanced among subjects. The PNF stretches included: static stretch (SS), contract–relax (CR), and agonist contract–relax (ACR). Two of these techniques (SS, CR) are considered “passive” stretches in that the stretch is administered to the subject manually. The ACR technique is considered an “active” stretch in that the subject stretches a muscle group via a voluntary contraction of the agonist muscle group. Prior to each stretch application, the subject’s knee was passively extended to a point of muscular restriction. This point was determined through a combination of the feedback from the subject indicating a point of resistance but not pain and a clinical soft tissue stretch “end feel” detected by the investigator. Previous investigations have reported high intra-tester reliability in determining range of motion when the appropriate use of end-feel and resistance was employed [22].

For SS, the subjects were asked to concentrate on relaxing the muscles of the leg and thigh as much as possible while the examiner passively extended the knee joint to the point of muscular restriction. Knee extension was gradually increased manually for 80 s during which ROM and EMG data were recorded (Table 1; Fig. 1B). It has been postulated that a gentle, sustained stretch will result in a mechanical viscoelastic stress relaxation-induced response and increase joint range of motion [23].

As with the SS condition, the CR stretch application began with the examiner passively extending the subject’s knee to a point of muscular restriction. When this position was attained, the subject was instructed to flex the knee with maximal force (isometric knee flexor contraction) against examiner resistance for 5 s. The subject was then instructed to completely relax the knee musculature while the examiner passively extended the knee for 5 s to a newly attained point of muscular restriction (phase 1). This procedure was then immediately repeated (phase 2). A trial consisted of two contractions each respectively followed by a 5 s interval of muscle stretch (phases 1 and 2). A total of four, two-phase trials (20 s each) were performed with ROM and EMG data collected during the passive muscle stretch (80 s total time; Table 1; Fig. 1C). It has been postulated that muscular inhibition is greater following an intense muscular contraction due to golgi tendon organ recruitment [3,23,24].

The ACR procedure began with the examiner passively extending the subject’s knee to the point of muscular restriction. When this position was attained, the subject was instructed to actively extend the knee with maximal force (concentric quadriceps contraction) for a
5-s period, thereby actively stretching the knee flexor muscles while the examiner manually assisted in knee extension. The subject was then instructed to relax the thigh musculature while the knee was maintained by the examiner at the obtained stretched position for 5 s (phase 1) after which the procedure was repeated a second time (phase 2). A trial consisted of two contractions (active knee flexor stretch) each respectively followed by a 5-s interval of muscle relaxation (phases 1 and 2). A total of four, two-phase trials (20 s each) were performed with ROM and EMG data collected during the active muscle stretch (80 s total time; Table 1; Fig. 1D). It is believed that intense quadriceps contraction will cause reciprocal inhibition of knee flexor musculature resulting in decreased resistance to increasing knee extension range of motion [8,25].

Prior to data collection, subjects were allowed unlimited warm-up time, but were instructed not to include any stretching as part of the warm-up. Examples of preferred warm-up techniques included brief bouts of sub-maximal running and cycling. During testing, five minutes of rest between trials and conditions were given in order to limit fatigue. While resting, subjects lay quietly on the examination table. A brief questionnaire was administered following the experimental procedure. Subjects were asked to identify the PNF stretch procedure that was 1) most comfortable and 2) most uncomfortable.

### 2.3. Equipment

To measure changes in knee joint ROM, a Penny and Giles (Kistler, UK) electrogoniometer (ELGON) was aligned with the endblocks along the longitudinal axis of the knee joint with the center of the ELGON coil positioned coincident with the center of the knee joint coronal axis. To detect changes in muscle activation during the stretching procedure, bipolar silver/silver chloride (Beckman 650437, USA, 20 mm inter-electrode distance) surface EMG electrodes were applied to the skin parallel with the muscle fibers and overlying the muscle belly of the biceps femoris and lateral head of the gastrocnemius muscle. In order to achieve an optimal EMG signal and low impedance (< 5 kΩ), three, 4 cm² areas of skin were shaved, sanded and cleaned, and electrode gel applied between the skin and electrodes. An
additional electrode was placed on the muscle belly of the vastus lateralis. To test for the presence of possible intermuscle volume conduction of signals to electrodes, individual pretests of maximum voluntary isometric contractions were performed. No EMG phase or magnitude relationships between agonist and antagonist muscles were observed during these volitional contractions, indicating the independence of signals from each electrode.

EMG and ROM data were collected at 500 Hz using an Ariel Performance Analysis System (APAS, San Diego, CA) containing an analog to digital sampling module interfaced to a computer. High-gain bioamplifiers (Coulbourn S75-01; high and low cutoff frequencies of 8 and 1000 Hz, respectively; filter rolloff of 12 DB-octave⁻¹; input resistance of 10¹⁰ Ω) were used to amplify the EMG signals. EMG data were high-pass filtered at a cut-off frequency of 100 Hz using a dual-pass zero-order Butterworth filter, rectified, and integrated (trapezoidal technique: sample areas summed for each phase).

2.4. Data normalization

The effects of three PNF stretch techniques on three dependent variables were examined in this study: knee extension ROM and hamstring and gastrocnemius EMG activity. The ROM achieved for each stretching procedure was calculated as the change in knee extension ROM for each stretch condition reported as degrees of ROM. Mean EMG activity per unit time over the 80 s of total stretch from the hamstring and gastrocnemius muscle group during each stretch condition was computed as a percentage of the mean maximal EMG activity per unit time during a voluntary maximum isometric contraction of the same muscle group.

2.5. Statistical analyses

Data were analyzed using the statistical software package SPSS v10.0. Three repeat measure ANOVAs were computed in order to identify significant differences (p < 0.05), if any, in hamstring and gastrocnemius EMG activity and knee extension ROM achieved between the three stretch conditions. When the omnibus F-ratio indicated significant differences, planned comparisons were conducted via Scheffe’s post-hoc analysis test [26]. There were a total of 6 possible combinations of the order in which the stretch conditions could be applied. Each possible combination of the three stretch conditions was assigned a number from 1 to 6 and one additional general linear ANOVA was performed to detect any changes in total ROM achieved due to order of stretch application.

3. Results

An overall effect of stretch condition on ROM (F₂,₂₃ = 17.34, p < 0.05) and hamstring (F₂,₂₃ = 21.99, p < 0.05) and gastrocnemius (F₂,₂₃ = 23.68, p < 0.05) EMG was observed (Figs. 2 and 3). The ACR–PNF stretch condition produced the greatest gains in knee joint extension ROM as well as the greatest increase in knee flexor muscle EMG activity compared to CR and SS (Figs. 2 and 3). The average ROM produced during the ACR–PNF stretch procedure was 15.66±0.95° and was significantly greater than SS (11.67±0.82°) and CR (12.11±0.66°), respectively (Fig. 2). Hamstring and gastrocnemius EMG activity was significantly greater during the ACR–PNF stretch condition (42.07±4.16% and 25.81±3.74% respectively) than SS (19.52±2.38% and 11.76±1.27%) and CR (21.84±1.94% and 15.63±1.41%) respectively (Fig. 3). The results revealed no significant effects (F₂,₂₃ = 1.08 p > 0.05) of order of stretch application.

The results of the questionnaire indicated that 88% of the subjects found the SS and CR passive stretch techniques to be most comfortable and 77% of subjects found the ACR active stretch procedure to be most uncomfortable.
4. Discussion

The purpose of this study was to examine the effects of PNF stretch techniques on knee joint ROM and EMG activity in older adults. Based on the physiological changes that occur in individuals past the fourth decade of life, it was hypothesized that older adults would exhibit no differences in joint ROM or muscle EMG between the three PNF stretch techniques. In contrast to the hypotheses, an overall significant effect of condition was observed in that the ACR–PNF condition resulted in 29% and 34% greater knee joint extension ROM compared to CR and SS conditions, respectively. Furthermore, knee flexor muscle EMG activity (hamstring and gastrocnemius) in the ACR–PNF stretch technique demonstrated 92–115% and 65–119% greater EMG activity compared to the CR and SS stretch conditions, respectively. This finding was consistent with previous literature involving younger adults and suggests that PNF stretch techniques can be used to increase ROM in older adult populations and that PNF stretching does not result in decreases in muscle EMG activity.

Similar to the results of this investigation, Osternig et al. [8] reported a significant increase in hamstring EMG activity during the ACR–PNF condition as compared to the SS and CR stretch conditions. Osternig et al. [8] postulated that during the ACR stretch, considerable tension may develop in the hamstring muscles while undergoing eccentric loading and that this tension may increase muscle vulnerability to soreness and strain. Other investigations have reported similar findings and also supported the possibility that muscle injury can occur from eccentric loading of muscles and that care should be taken when applying the ACR–PNF stretch technique [6,7,9]. It is important to note that eccentric loading of the knee flexor muscles occurred when the knee was undergoing extension during the ACR stretch condition (Fig. 3). When the knee joint approached the end ROM during the ACR stretch procedure, an isometric contraction was most likely produced.

Since 77% of the subjects reported the ACR–PNF stretch procedure as the most uncomfortable of the three techniques, and as indicated by the increase in EMG activity in knee flexor muscles, considerable muscle tension may have been generated during application of active (ACR) PNF stretching. It is possible that significant increases in ROM and muscle EMG activity produced during the ACR stretch condition have the potential to increase muscle vulnerability to soreness and injury in older adult populations. An overall increase in type I collagen and a decrease in type III collagen occurs in adults past the fourth decade of life, which may add stiffness to the musculotendinous unit [19,27]. Increased stiffness would thereby create increased resistance to stretch, reduced elastic compliance, and diminished functional performance especially in type I slow oxidat-
ive muscle tissue, predominant in individuals past the fourth decade of life [19,27]. Blaniped et al. [16] studied differences in plantarflexor muscles stiffness between young and elderly females and reported that elderly adults exhibited greater stiffness during a passive stretch procedure. Animal studies have also suggested that older muscles exhibit greater muscle stiffness [19,27–29] not due to a reflex response, but due to non-reflex factors such as non-elastic connective tissue replacing degenerated active muscle fibers [28]. McHugh et al. [30] studied the effect of eccentric loading on muscle damage in “stiff”, “compliant”, and “normal” young adults. It was reported that strength loss, pain, muscle tenderness, and chemical mediators indicative of muscle damage were significantly greater in the stiff as compared to the compliant group. In addition, it has been suggested that increased deposition of inextensible adipose and connective tissue could result in greater tension per unit increase in joint ROM due to increased elastic stiffness of the musculotendinous unit especially near the end of joint ROM [16,17,31].

The present investigation demonstrated that PNF stretch procedures were effective in increasing knee joint ROM in older adults (Fig. 2). Other investigations have reported that the SS passive stretch technique is an effective method of increasing joint ROM in elderly subjects [10,32]. Feland et al. [32] determined which of three durations of SS stretch techniques (15, 30, and 60 s) produced the greatest gains in knee extension ROM in a group of elderly individuals. The results indicated that a 60-s stretch produced a greater rate of gain in ROM compared to 15 and 30 s durations, resulting in an increase of approximately 14.4° over six weeks. Although the passive stretch procedures (SS and CR) used in the present investigation were not administered over multiple days, the results from the present investigation are in agreement with Feland et al. and suggest that passive stretch techniques can be used to increase joint ROM in older adults. In addition, Ferber et al. [10] studied the same PNF techniques used in the present investigation in endurance-trained and untrained older adults. It was reported that PNF stretch techniques can be used to produce increases in knee joint extension ROM in older adult populations but that no differences between the three stretch techniques were observed in the 65–75 year-old untrained group. It was suggested that the 65–75 year-old untrained group possibly lacked the muscular strength and/or neuromuscular coordination necessary to produce a sustained concentric knee extensor torque while undergoing the active ACR antagonist stretch.

From a clinical standpoint, it is suggested that care should be taken upon application of PNF stretch techniques in older adults to prevent unnecessary muscle damage. Osternig et al. [8] reported a reduction in hamstring EMG activity during the 80-s SS stretch technique...
in younger adults and suggested that passive stretch techniques may be safer than active techniques such as the ACR procedure. A reduction in knee flexor EMG activity was not observed in the present investigation, but 88% of subjects reported that the passive stretch procedures (SS and CR) were the most comfortable. In addition, Ferber et al. [10] postulated that sedentary older adults possibly lacked the neuromuscular coordination to appropriately perform the ACR stretch technique. Therefore, stretching of aged muscles using a passive stretch technique (SS or CR) is recommended for older adult populations.

Several limitations were present in this investigation and should be discussed along with future research directions. The point of musculature restriction used for each of the three stretch techniques was determined through a combination of feedback from the subject indicating a point of resistance but not pain and a clinical soft tissue stretch “end feel” detected by the investigator. While changes in joint position may have influenced the results of this investigation, pilot studies performed prior to data collection indicated high reliability in reproducing the same joint position between trials. Pilot testing indicated that a change in the initial ROM position between trials and conditions was not more than 5°. This finding suggests that small changes in the initial point of musculature restriction may not have significantly influenced the results of the present investigation. Since the examiner was not blinded to the type of stretch being applied, some bias may have been introduced in the results. However, all stretch techniques were applied by the same examiner who was trained in the clinical application of PNF techniques. Incorporating an examination of the Hoffmann reflex (H reflex) may shed some light onto the phenomenon of muscle inhibition. Condon and Hutton [6] measured H-reflex amplitude and postulated that reciprocal inhibition was occurring during the active PNF stretch procedure but was possibly masked by other neurogenic excitatory impulses to the antagonist motor-neuron pool. Finally, the amount of muscle tension generated during the active and passive PNF stretch techniques was not directly measured in this study. Magnusson et al. [33] reported no differences in passive joint torque or EMG response between the CR and SS PNF stretch techniques but the ACR–PNF condition was not studied. Examination of the joint torque produced during application of active PNF stretch techniques may help to better understand the observation that PNF stretch techniques that produce the greatest gains in joint ROM may also produce the greatest increase in antagonist EMG activity.

5. Conclusion

PNF stretch techniques can be used to increase ROM in older adult populations. In addition, older adults exhibit a similar response to PNF stretch techniques as compared to previous literature involving younger adults in that the ACR–PNF stretch technique achieved greater knee joint ROM and muscle EMG activity compared to the CR and SS stretch conditions.

Acknowledgements


References


